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ORIGINAL ARTICLE

Prevalence of Pathogenic Bacteria and Antibiotic Susceptibility Profiles Isolated from Medical Equipment and Inanimate Surface

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SUMMARY

Background: **The hospital environment, especially the intensive care unit, is a leading reservoir of nosocomial bacteria. Equipment and inanimate surfaces are among the most transmission vehicles for nosocomial bacteria. This study is to assess the bacterial profile and antibiotic susceptibility pattern of the isolates from medical equipment and inanimate surfaces at intensive care unit wards in Bahir Dar City government hospital, North West Ethiopia.**
Methods: **A hospital-based, cross-sectional study was conducted between March 01/2021 and May 30/2021 at Felege Hiwot and Tibebe Gihon Compressive Specialized Hospitals. A total of 158 surface swab samples from the patient bed, table, chair, sphygmomanometer, and stethoscopes were collected. Sterile cotton-tipped swabs moistened with normal saline were used. Using standard protocols, the collected samples were processed at Bahir Dar University, Microbiology Laboratory. All isolates were cultured and identified by using routine bacterial culture, Gram staining, and biochemical tests. Phenotypic antimicrobial susceptibility testing was done on each isolate following the Kirby Bauer disk diffusion method. Data were entered and analyzed using SPSS version 26 and the results were explained by using percentages and tables.**
Results: **In this study, coagulase-negative *Staphylococcus, S. aureus,* and *K. pneumoniae* were the most predominant isolated bacteria, which accounted for 52.8%, 47.2%, and 43.2% respectively. Chairs, sphygmomanometers, and patient beds were the most contaminated. Imipenem and clindamycin were the most effective antibiotics for all Gram-negative and Gram-positive isolates, respectively. Among the total isolates, 84 (57.5%) were multidrug resistant and of these, 78.4% were Gram-negative isolates.**
Conclusions: **Inanimate objectives and key medical devices of the hospital are heavily contaminated with potentially pathogenic bacteria. Additionally, the recovered isolates are multidrug resistant, making the control and prevention strategy more challenging. Thus, the hospital infection prevention and surveillance system must be activated and perform periodic disinfection of objects. Furthermore, large-scale surveillance is desirable.**
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KEYWORDS

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INTRODUCTION

The hospital environment, especially intensive care units (ICU), is a common reservoir of nosocomial pathogens and plays an important role in bacterial transmis-

sion [1]. It contains diverse antibiotic-resistant bacteria and mobile genetic elements [2,3]. Inanimate surfaces of wards and medical devices are the most common components of the ICU environment and are responsible for the transmission vehicle for nosocomial infections (NIs) [4]. Bacterial cross-contamination plays an important role in the transmission of such types of infections and the dissemination of resistant strains [5].

In ICUs, even after adopting strict sanitation protocols, many patients are infected with hospital-acquired infections (HAIs)/NIs [6]. Hospital-acquired infections/nosocomial bacterial infections are infections that are acquired by the patient within 48-72 hours of admission, and are associated with interventions, devices, or procedures carried out in hospital or within 30 days after discharge [7]. These infections are a major challenge for low and middle-income countries (LMICs) which have limited healthcare resources [8].

Patients admitted to the ICU are at high risk for acquiring different hospital-acquired infections, such as central line-associated bloodstream infections, catheter-associated urinary tract infections, ventilator-associated pneumonia, and surgical site infection [9].

The major sources of transmission of nosocomial infections are patients, medical personnel, and inanimate objects/equipment (patient bed, side table, chairs, catheters, syringe pumps, sphygmomanometer, thermometer) to the patients, visitors, or health medical staffs [10,11]. Inappropriate use of antibiotics, invasive medical procedures, underlying diseases, impaired immunity, and prolonged hospitalization further increase the NIs transmission [10].

Studies have reported many organisms responsible for nosocomial bacterial infection, including coagulase-negative staphylococci (CoNS), *Staphylococcus aureus, Enterococcus, Streptococcus, Klebsiella* species*., Acinetobacter, Escherichia coli, Salmonella, Shigella, Klebsiella, Proteus* species, and *Pseudomonas* species [12, 13]. Organisms causing these infections are often present on surfaces around the patient [10]. Moreover, the ICU ward of the environment itself is an epicenter of pathogens due to bacteria forming biofilms and being considered "survival specialists" [14]. Those biofilms may enhance bacterial survival on dry surfaces, humid and/or low-temperature conditions, and may confer resistance to physical and chemical agents [15].

Antimicrobial agents are often categorized according to their principal mechanism of action and those mechanisms include interference with cell wall synthesis, inhibition of protein synthesis, interference with nucleic acid synthesis, inhibition of a metabolic pathway, and disruption of the bacterial cell membrane [16]. Some bacteria also acquire resistance by mutation or through conjugation, transformation, or transduction [17].

Infections caused by multidrug-resistant (MDR) bacteria are a worrisome health care problem and a tremendous effect in a daily challenge for the clinician dealing with critically ill patients [18]. Because the majority of nosocomial bacterial pathogens are now becoming superbugs and new resistance problems have emerged recently among hospitals such as carbapenem-resistant *Entrobacteriaceae*, methicillin-resistant *S. aureus*, extended-spectrum beta-lactamase-producing *Entrobacteriaceae*, vancomycin-resistant *Enterococcus*, MDR-*P. aeruginosa*, MDR- *Acinetobacter* and *C. difficile* [19, 20]. However, such data are limited in medical equipment and inanimate surfaces at intensive care unit wards in Ethiopia; therefore, we designed a study to assess bacterial profiles and antibiotic susceptibility patterns of the isolates from medical equipment and inanimate surfaces at intensive care unit wards in Bahir Dar City government hospitals.

MATERIALS AND METHODS

Study design, period, and area

A hospital-based cross-sectional study was conducted from March 01, 2021, to May 30, 2021. The study was undertaken on medical types of equipment and inanimate objects at the ICU ward of Felege Hiwot Comprehensive Specialized Hospital (FHCSH) and Tibebe Gion Specialized Hospital (TGSH), Bahir Dar, Ethiopia. According to the information of the manager of the hospital, Felege Hiwot Comprehensive Specialized Hospital is one of the largest hospitals in Bahir Dar, which was established in 1952 and serves more than 10 million people of Bahir Dar and the surrounding zones and regions. The hospital has 13 wards, 430 beds, and about 631 health professionals. The general ICU of FHCSH is one of the largest in the Amhara region, which has 2 rooms, 12 beds, and serves more than 20 patients per week. Moreover, TGSH of Bahir Dar University has located about 10 km to the south of Bahir Dar city center. According to the manager, it has 10 wards, 354 beds, and about 593 health professionals. The hospital also has an ICU having 2 rooms, 8 beds, and more than 15 patients per week. Generally, both hospitals have their main missions, including quality services and training for rehabilitation, surgery, dermatology, ophthalmology, and other relevant infectious diseases.

Study group, sample size, and sampling technique

The source of the group was all medical equipment and inanimate objects which were found in the ICU ward. Study group were the most touched medical equipment and inanimate objects which are suspected to harbor bacterial pathogens. Most high surface touching medical equipment and inanimate objects (stethoscopes, sphygmomanometers, patient beds, tables, and chairs) were included in the study. Those medical equipment and inanimate objects (stethoscopes, sphygmomanometer, patient bed, table, and chair) which had visible particles during data collection were excluded from this study. The sample size was calculated based on a single population proportion formula and the calculated sample size was 158. The value of proportion (P) was taken

as 88.5% (0.885) from the previous study conducted by Darge et al. [21]. The calculated sample size was allocated proportionally to each health facility based on their number of materials (equipment and inanimate object) which were functional in the study period. Convenience sampling techniques were used from in the ICU ward until the required sample size was achieved. To select representative participants, the final sample size was proportionally allocated to each stratum. Therefore, 158 (96 swab samples from FHCSH and 62 swab samples from TGSH) were included.

Laboratory methods

Bacteriological sample collection, transportation, and processing

The specimens were collected from the general ICU ward of FHCSH and TGSH from commonly touched medical equipment and inanimate objects including stethoscopes, sphygmomanometer, patient bed, tables, and chairs (each 1.5 cm^2 surface area) using a sterile cotton swab moistened with normal saline. All swab samples were collected every morning (before the commencement of work). Following collection, all swab specimens were inserted into a separate sterile test tube and labeled with sample number, sample type, time, and date of sample collection. After collection, all swab samples were transported to Bahir Dar University (BDU) Microbiology Laboratory and processed within 1 hour. For TGSH, swab specimens were transported in Amie's transport media using a sample carrier.

Bacterial Isolation and Identification

Microbiological analysis of swab specimen: After the swab specimens have been collected, potential pathogenic bacteria were identified by inoculating/streaking of the swab on MacConkey agar (Oxoid Ltd, Basingstoke, UK) and blood agar based on their color morphology after an incubation time of 18 - 24 hours at 37°C. The smear was prepared from each different colony observed on the plates and Gram staining was performed. The results such as gram reaction (Gram-negative and Gram-positive), arrangements, and shape of bacteria are seen from the examinations using a microscope [22].

Culture observation: Preliminary identification of bacteria was done based on the colony characteristics of the organisms. Some colony characteristics include size, shape, color, pigmentation, texture, elevation, edge, and hemolysis on blood agar, changes in physical appearance in differential media, and enzyme activities of the organisms [23].

Biochemical examination: Biochemical tests were performed on colonies from pure cultures for identification of the isolates. Gram-negative rods were identified by performing a series of biochemical tests using triple sugar iron agar (TSI), sulfide indole motility (SIM) test, Simmons's citrate agar, and urea. Oxidase test was used to confirm *Pseudomonas aeruginosa*. Gram-positive cocci were identified based on their Gram-reaction and catalase test was used to differentiate *Staphylococci from Streptococci.* Coagulase test was used to differentiate *S. aureus* from CoNS, and all catalase-positive results were sub-cultured on mannitol salt agar at 37°C for 18 - 24 hours [24].

Antimicrobial susceptibility testing

The AST of the isolate was performed by modified Kirby-Bauer disk diffusion technique following the Clinical and Laboratory Standard Institute (CLSI) guideline [25]. A loop full of bacteria (2 - 3 identical colonies) were taken by a sterile wire loop from a pure culture colony and transferred to a test tube containing 5 mL of normal saline and mixed gently until it forms a homogenous suspension [25]. To standardize the density of the inoculum, the turbidity of the homogenous suspension was prepared and adjusted to 0.5% by a turbidimetric reader. The test organism was uniformly seeded on MHA (Oxoid, Basingstoke, and Hampshire, UK) using the lawn culture method. The following antibiotics disks were used as penicillin group (penicillin (p, 10 µg), and Ampicillin (AMP, 10 µg), β-lactam combination group (Amoxicillin/clavulanic acid (AUG 20/10 µg), Beta-lactams (Cefotaxime (CTX 30µg), Ceftazidime (CAZ 30 µg), and Ceftriaxone (CRO 30 µg),), Aminoglycosides (Gentamicin (GEN 10 µg)), Carbapenem (*Imipenem* (IM 10 µg)), Tetracycline (Tetracycline (TE 30 µg), Fluoroquinolones (Ciprofloxacin (CIP 30 µg)), Phenicols (Chloramphenicol (CHL 30 µg)), and Sulfonamide (Trimethoprim/Sulphamethoxazole (23.75 µg/1.25 µg), Nitro furans (Nitrofurans (Nit 300 µg)), Macrolides (Erythromycin (ERY 15 µg), and Lincosamide (Clindamycin (CLN 2 µg). The antibiotic disks used were from BD, BBL™ Company, USA Product. Then the plates were incubated at 37°C for 24 hours. Diameters of the zone of inhibition around the discs were measured to the nearest millimeter using a ruler and the isolates were classified as susceptible, intermediate, and resistant according to the standardized table supplied by the CLSI guideline [25]. Multi-drug resistance patterns of the isolates were identified using the criteria set by Magiorakos et al. [26].

Quality control

The reliability of the study findings was guaranteed through the implementation of standard quality control measures throughout the whole process of the laboratory work. Before swab specimen collection, all materials (cotton-tipped applicator sticks, normal saline test tube, and Amies transport media) were sterilized by autoclaving at a pressure of 15 lb/in^2 at 121°C for 15 minutes. During the processing and interpretation of the results the standard operating procedures (SOPs) of the Microbiology Laboratory of BDU were incorporated and strictly followed. All culture media was prepared by the manufacturer's instructions and sterilized at a pressure of 15 lb/in^2, 121°C for 15 minutes. The sterility of culture media was checked by incubating 5% of each batch of the prepared media at 37ºC for 24 hours and

Table 1. Number of screened equipment/objects by study hospital in Bahir Dar city government hospital, March to May 2021 (n = 158).

Name of Hospitals	Name of Equipment and inanimate objects					
	Bed (n)	Chair (n)	Table (n)	Sphygmomanometer (n)	Stethoscopes (n)	Total
FHCSH	24	16	14	22	20	96
TGSH	16	16	12	8	10	62
Total	40	32	28	30	30	158

FHCSH - Felege Hiwot Comprehensive Specialized Hospital, TGSH - Tibebe Gihon Specialized Hospital.

Table 2. Proportion of bacterial isolates by type of equipment/ objects at ICU ward in Bahir Dar city governmental hospital, March to May 2021.

Equipment/object screened	Total sample examined	Positivity rate n (%)
Bed	40	34 (85%)
Chair	32	30 (93.8%)
Table	26	22 (84.6%)
Sphygmomanometer	30	28 (93.3%)
Stethoscope	30	24 (80%)
Total	158	138 (87.3%)

Table 3. Distribution of bacterial isolates by type of equipment/object in ICU ward in Bahir Dar city governmental hospital, March to May 2021.

Organism isolated	Total	Types of equipment and inanimate objects				
		Bed n (%)	Chair n (%)	Table n (%)	Sphygmomanometer n (%)	Stethoscope n (%)
S. aureus	*34*	14 (41.2)	12 (35.3)	4 (11.8)	2 (5.9)	2 (5.9)
CONS	*38*	16 (42.1)	8 (21.1)	8 (21.1)	4 (10.5)	25.25)
K. pneumoniae	*32*	2 (6.25)	6 (15.8)	6 (15.8)	8 (21.1)	10 (31.3)
K. oxytoca	6	0 (0)	2 (33.3)	0 (0)	2 (33.3)	2 (33.3)
E. coli	20	4 (20)	4 (20)	2 (10)	6 (30)	4 (20)
P. aeruginosa	12	2 (16.7)	0 (0)	2 (16.7)	4 (33.3)	4 (33.3)
Enterobacter spp.	4	0 (0)	2 (50)	0 (0)	2 (50)	0 (0)
Total	146	38 (26)	34 (23.3)	22 (15.1)	28 (19.2)	24 (16.4)

observed for the presence of any growth [27,28]. Any physical changes like cracks, excess moisture, color, hemolysis, dehydration and contamination were checked before use of all culture media. The expiration date of all reagents was checked strictly. The temperature of the incubator and refrigerator was monitored daily. To standardize the inoculum density of bacterial suspension for AST, 0.5 McFarland turbidity standard was used. All prepared media were checked by inoculating standard reference strains, *S. aureus* (ATCC® 29213), *E. coli* (ATCC® 25922), and *P. aeruginosa* (ATCC® 27853) as quality control during the study period for culture, Gram stain, and AST. In addition, well-trained and experienced laboratory professionals have participated in

Table 4. Resistance patterns of bacterial isolates from equipment/objects at ICU ward in Bahir Dar city governmental hospital, March to May 2021.

Bacterial Isolates	Antibiotic tested for Gram-negative isolates										
	AMC	C	CIP	TE	CAZ	CRO	SXT	GEN	NIT	IMP	AMP
K. pneumoniae (n = 32) (%)	16 50	12 37.5	10 31.3	18 56.3	6 18.8	20 62.5	10 31.3	8 25	6 18.8	0 0	32 100
K. oxytoca (n = 6) (%)	4 66.7	2 33.3	2 33.3	4 66.7	2 33.3	2 33.3	2 33.3	2 33.3	2 33.3	0 0	6 100
E. coli (n = 20) (%)	12 60	8 40	6 30	8 40	4 20	10 50	8 40	8 40	4 20	0 0	9 45
P. aeruginosa (n = 12) (%)	12 100	12 100	4 33.3	12 100	4 33.3	12 100	12 100	6 50	4 33.3	2 16.6	12 100
Enterobacter spp. (n = 4) (%)	4 100	2 50	0 0	0 0	0 0	2 50	0 0	0 0	0 0	0 0	4 100
Total	48 64.9	36 48.6	22 29.7	42 56.8	16 21.6	46 62.2	32 43.2	24 32.4	16 21.6	2 2.7	63 85.1
Bacterial Isolates	Antibiotic tested for Gram-positive isolates										
	P	C	CIP	TE	E	DA	SXT	GEN	NIT		
S. aureus (n = 34) (%)	20 58.8	12 35.5	8 23.5	16 47.1	14 41.2	0 0	12 35.5	11 32.4	8 23.5		
CONS (n = 38) (%)	16 42.1	13 34.2	8 21.1	14 36.8	14 36.8	4 10.5	8 21.1	8 21.1	8 21.1		
Total	36 50	25 34.7	16 22.2	30 41.7	28 38.9	4 5.6	20 27.8	19 26.4	16 22.2		

AMC - Amoxicillin/clavulanic-acid, AMP - Ampicillin, C - Chloramphenicol, CAZ - Ceftazidime, CIP - Ciprofloxacin, CoNS - Coagulase Negative Staphylococcus, CRO - Ceftriaxone, DA - Clindamycin, E - Erythromycin, GM - Gentamicin, IMP - Imipenem, NIT - Nitrofurantoin, P - Penicillin, SXT - Trimethoprimsulfamethoxazole, TE - Tetracycline.

Table 5. Antibiogram profile of isolated bacteria from equipment/objects of ICU ward in Bahir Dar city governmental hospital, March to May 2021.

Bacterial isolates	Antibiogram pattern					
	R0	R1	R2	R3	R4	≥ R5
S. aureus (n = 34)	0 (0)	6 (17.6%)	18 (52.9%)	8 (23.5%)	2 (6%)	0 (0)
CONS (n = 38)	18 (47.4%)	4 (10.5%)	0 (0)	12 (31.6%)	4 (10.5%)	0 (0)
K. pneumoniae (n = 32)	0 (0)	0 (0)	4 (12.5)	4 (12.5)	10 (31.3)	14 (43.5%)
E. coli (n = 20)	2 (10%)	4 (20%)	4 (20%)	2 (10%)	8 (40%)	0 (0)
P. aeruginosa (n = 12)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	12 (100%)
K. oxytoca (n = 6)	0 (0)	0 (0)	2 (33.3%)	2 (33.3%)	0 (0)	2 (33.3%)
Enterobacter species (n = 4)	0 (0)	0 (0)	0 (0)	2 (50)	2 (50%)	0 (0)

CONS - Coagulase Negative *Staphylococcus*, R0 - No antibiotic resistance, R1 - Resistance to one, R2 - Resistance to two, R3 - Resistance to three, R4 - Resistance to four, ≥ R5 - resistance to five classes and above.

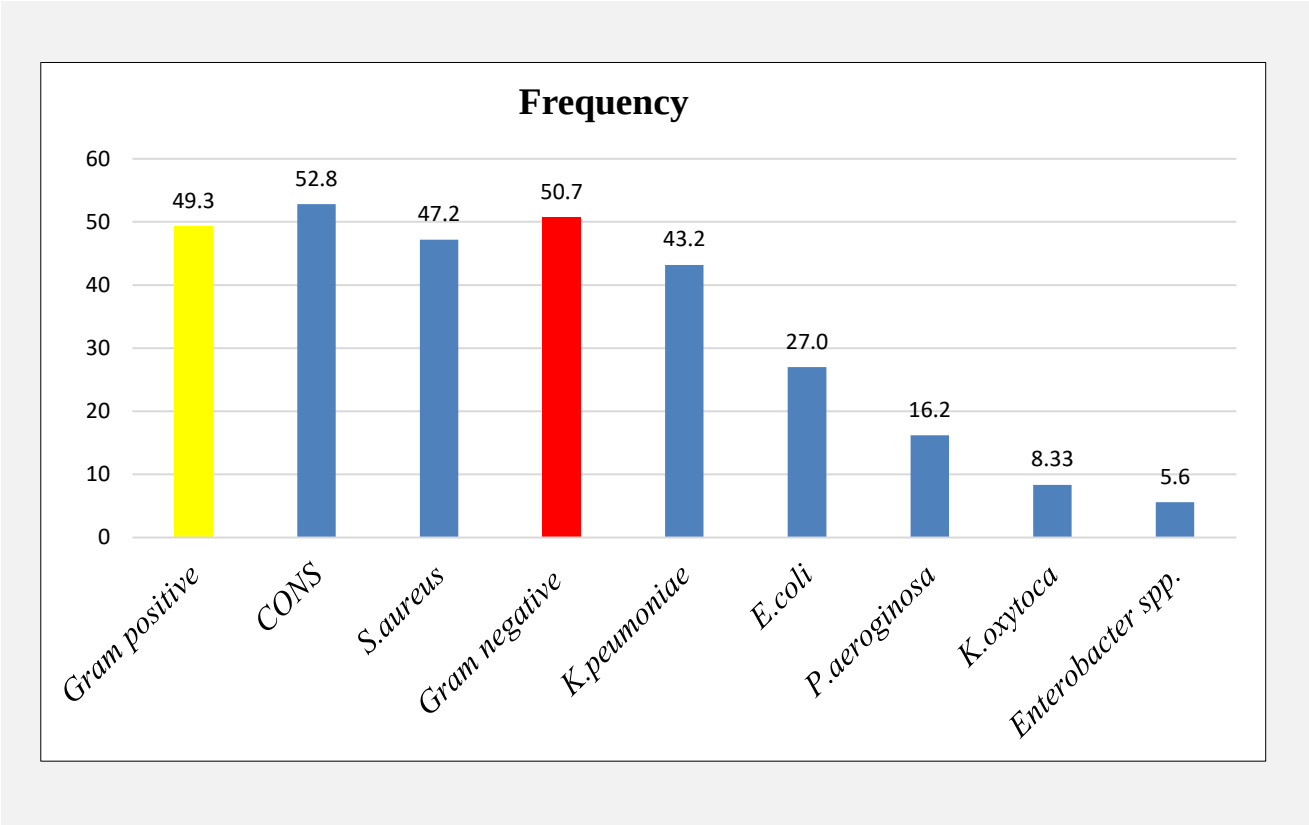

Figure 1. The proportions of isolated bacteria at ICU ward in Bahir Dar city governmental hospital, March to May 2021.

the laboratory analysis procedure. All laboratory test results were interpreted based on the SOPs of BDU Microbiology Laboratory and 2020 CLSI guidelines

Data processing and analysis

All data were checked for completeness, coded, entered, and analyzed using statistical Package for Social Sciences (SPSS) Version 26 software. Then descriptive statistics were calculated using frequencies and cross-stabs.

Ethical approval

The protocol (Protocol number 153/2021) of this study was approved by the Institutional Ethical Committee, College of Medicine and Health Sciences, Department of Medical Laboratory Sciences, BDU (Support letter was obtained from BDU. Then, FHCSH and TGSH forwarded the letter to the respective units for potential support of the project.

RESULTS

Characteristics of screened equipment/objects included in the study

During the study, a total of 158 swab samples were collected in the ICUs ward from the patient beds, chairs, tables, sphygmomanometers, and stethoscopes. Of these, 40 swab sample were from patient beds, 32 (chairs), and 28 (tables), from Sphygmomanometer and stethoscopes (30 each) (Table 1).

Culture results and proportions of bacterial isolates

Among a total of 158 swabs samples, 138 (87.3%) were culture positive for bacterial growth (84; 87.5%) from FHCSH and 54 (87.1%) from TGSH, and a total of 146 bacterial isolates were identified. Eight swab samples (5.1%) having mixed growth (*S. aureus* and *E. coli*) were detected from the patients' beds and chairs. Out of 146 bacterial isolates, 74 (50.7%) were Gram-negative bacteria and the remaining 72 (49.3%) were Gram-positive bacteria. Coagulase-negative staphylococcus (38; 52.8%) and *S. aureus* (34; 47.2%) were detected in Gram-positive bacteria. On the other hand, *K. pneumoniae* (32; 43.2%) were the most predominant bacteria followed by *E. coli* (20; 27%) and *P. aeruginosa* (12; 16.2%) from Gram-negative isolates. The proportion of each bacterial isolate is shown in (Figure 1).

The proportion of bacterial isolates by type of equipment/inanimate object

From the total 158 swab samples, the highest bacterial contamination rate was observed in Chair (93.8%), followed by Sphygmomanometer (93.3%), and patient bed

(85%). The positive rate of each item is summarized in the table below (Table 2).

Distribution of bacterial isolates by type of equipment/ objects

The highest bacterial contaminated samples were taken from the chair and patient bed, which were contaminated with CONS (16/42.1%), and *S. aureus* (14/41.2%), respectively. *K. pneumoniae* were the most common Gram-negative bacteria isolated from stethoscopes (10/31.3%) and Sphygmomanometer (8/21.1%). The distributions of bacterial contamination of inanimate objects and medical devices are described below (Table 3).

Antimicrobial susceptibility profiles of isolated bacteria

A total of fourteen antibiotics from 12 classes were used to assess the susceptibility profile of the isolates. As such, most of the Gram-negative bacteria had high resistance to ampicillin (85.1%), amoxicillin/clavulanic acid (64.9%), and ceftriaxone (62.2%). In contrast, imipenem was the most effective antibiotic for all Gram-negative isolates with a sensitivity of 97.3%. Gram-positive isolates were resistant to penicillin (50%), tetracycline (41.7%), and erythromycin (38.9%). However, clindamycin (100% sensitivity) was the most effective antibiotic for *S. aureus* isolates. *S. aureus* was sensitive to Gentamycin and Chloramphenicol (88.2% each). Coagulase-negative *staphylococcus* was sensitive to Clindamycin, Gentamycin, and ciprofloxacin (89.5% each) (Table 4). Most of the bacterial isolates (84; 57.5%) showed multidrug resistance (MDR) to three and/or more classes. Of this, 58 (78.4%) were Gram-negative. From Gram-negative isolates, *P. aeruginosa* (100%) was resistant to ≥ R5 classes tested. Similarly, *K. pneumoniae* also was resistant to three, four, and five classes tested (12.5%, 31.3%, and 43.5%, respectively). *Escherichia coli* (40%) also was resistant to the four classes tested. Of Gram-positive bacteria, CoNS were resistant to three and four classes (31.6%, 10.5%, respectively) (Table 5).

DISCUSSION

In this study, out of 158 swab samples, 138 (87.7%) were positive for bacterial contamination. This is relatively in agreement with other study results in Nepal 94.4% [29], Cameron 94.7% [30], and Mekelle-Ethiopia 88.5% [21]. However, it is higher than lower bacterial contamination which was reported from studies conducted in Nigeria 29.6% [31]. The differences might be study time and place, infection prevention practice of the facilities, difference in hand hygiene, the ventilation system of the ICU, sterilization, and disinfection techniques.

The results of this study showed that the ICU room was contaminated by different types of bacteria. Of these, 74 (50.7%) were GNB and 72 (49.3%) were GPB. Overall, CoNS (38; 52.8%) was the most frequently isolated bacteria, which is relatively similar to the previous studies conducted in Nigeria 39.4% [32] and Mekelle-Ethiopia 34.9% [21]. However, it is inconsistent with the studies conducted in Navi Mumbai 14.6% [33], Cameron 8.7% [30], Nigeria 14.8% [31], and Mizan-Tepi-Ethiopia 19.3% [12]. These variations may be due to different sampling times (e.g., during endemic versus outbreak situations), the presence of already colonized and/or infected patients during sample collection, infrequent cleaning of inanimate surfaces and medical equipment.

In this study, *S. aureus* (34; 47.2%) was the second most prevalent bacteria isolated in the ICU ward on medical equipment and inanimate surfaces which correlates with the report done in Nigeria (50.7%) [31]. However, it is contradicted in the studies that were conducted in Navi Mumbai 15% [33], Mekelle-Ethiopia 26.3% [21], and Mizan-Tepi-Ethiopia 21.6% [12]. These observed differences could be attributed to several factors like the presence of underlying clinical conditions and immune debilitated patients in the study setting (ICU room). Moreover, *S. aureus* constitutes part of the normal human flora, inhabiting the skin mucous membranes, and might be regularly shed into the ICU environment by patients and medical personnel, whereupon they persist [34].

Similarly, in this study, *K. pneumoniae* 32(43.2%), was the most prevalent GNB isolated in the ICU ward of medical equipment/inanimate surface, and it is higher than the study conducted in Navi Mumbai 6.25% [33], Cameron 6.6% [30], Nigeria 7.04% [31], 13.2% [32] and Jimma-Ethiopia 14.9% [12] and Mekelle-Ethiopia 8% [21]. During the study period, these discrepancies might be the presence of secretions in colonized patients in the unit or contaminated staff hands, contaminated equipment/inanimate surface. In this study, *E. coli* (20; 27%) was the second reported GNB, and it is higher than the previous study conducted in Nigeria, Benue State (15.5%) [31], in Nigeria, Borno state (10.5%) [32], and Mekelle-Ethiopia (15.9%) [12]. The discrepancies of this result might be seasonal variation and differences in geographical location. Moreover, *P. aeruginosa* (12; 16.2%) was the third reported GNB, and it was almost similar to the study that was done in Navi Mumbai 7.5% [33], Cameron 22.6% [30], and Mizan-Tepi-Ethiopia 11.4% [12].

Among the different medical equipment and inanimate objects examined, patient beds and chairs are mainly contaminated by CoNS (16; 42.1% and 8; 21.1%, respectively) and *S. aureus* (14; 41.2% and 12; 35.3%, respectively). This is comparable with studies conducted in Mekelle-Ethiopia [21]. Isolation of these organisms from the equipment/inanimate object might be an indication of possible contamination from patients and staff handling or lack of cleaning. Also, most *Staphylococcus* species are harbored by many colonized patients as normal flora of the skin as well as the respiratory tract and

might be transmitted to the patient beds and chairs via coughing and sneezing [35]. Clinical equipment such as stethoscopes and Sphygmomanometer were mainly contaminated by GNB such as *K.pneumoniae, P. aeruginosa,* and *E. coli.* The possible reason might be those materials are in direct contact with the patient skin during examination [36-38].

With regard to the antimicrobial resistance profile of the isolates, these results showed high proportions of drug resistance, where most of the GNB were highly resistant to most of the tested antibiotics such as ampicillin (85.1%), amoxicillin/clavulanic acid (64.9%), and ceftriaxone (62.2%) which is in line with results reported in Mekelle-Ethiopia [21]. In this study, *P. aeruginosa* (100%) was resistant to amoxicillin/clavulanic acid, chloramphenicol, tetracycline, ceftriaxone, and Trimethoprim sulfamethoxazole, which is in line with similar resistance rates from other studies conducted in Navi, Mumbai [33], Cameron [30], and Jimma-Ethiopia [39]. In contrast, imipenem was effective in all Gram-negative isolates with a sensitivity rate of 97.3%. Moreover, Ciprofloxacin, Ceftazidime, and Nitrofurantoin were relatively effective against most of the bacterial isolates. This finding is in agreement with the findings of other studies, like Sudan [40], Jimma-Ethiopia [39], Mizan-Tepi-Ethiopia [12], and Mekelle-Ethiopia [21]. Clindamycin was the most effective antibiotic for *S. aureus and* CoNS (100% and 89.5% sensitivity, respectively), and which was comparable to the study done in Nepal 85% [29] and Jimma-Ethiopia 89.6% [39]. However, it had higher resistance for Penicillin (58.8%), and Erythromycin (41.2%) which was similar to the study of Nepal [33], Sudan [40], and Nigeria [31]. In this study, multidrug resistance was seen in 36.1 % of Gram-positive and 78.4% of the Gram-negative isolates which was in line with other studies conducted in Jimma-Ethiopia [39].

Limitations of the study

The present study has the following limitations:

Anaerobic bacteria were not isolated due to lack of set-up in the working area and there was the limitation of antibiotics like methicillin and cefoxitin to screen and confirm methicillin resistance to *Staphylococcus aureus.* Antibiotic resistance encoding genes (ARGs) of the isolates were not detected as a confirmatory test due to a lack of molecular techniques and primers.

Conclusions and Recommendations

In this study, medical equipment and inanimate objects especially, such as chairs, sphygmomanometers, and patient beds are contaminated with various types of bacteria. Of these, coagulase-negative *Staphylococc*i were the predominant bacterial type, followed by *S. aureus* and *K. pneumoniae*. Chairs, sphygmomanometers, and patient beds were the most contaminated. Imipenem and clindamycin were the most effective antibiotics for all Gram-negative and Gram-positive isolates, respectively. The frequency of MDR bacteria in Gram-negative isolates was alarmingly high. This might be cross-contamination between patients and equipment/objects, indiscriminate use of antibiotics, or unavailability of a guideline regarding the selection of drugs.

Based on the findings, the following recommendations are forwarded to hospital administrators, other stakeholders, and all health professionals of the hospital. All professionals give special attention to infection prevention policies such as good clinical practice, proper handling, and disinfection of equipment/inanimate surfaces. Antimicrobial treatment should be based on the result of culture and sensitivity. In hospital settings, the use of antimicrobials and antimicrobial resistance screening needs to be monitored. Additionally, the government at all tiers should give attention to sponsoring research on large-scale investigations in the hospital setting.

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Declaration of Interest:

The authors declare that they have no competing interests.

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